2nd Sino-German Symposium

Material-Oriented Micro-Nano Manufacturing: Modeling, Experiment and Application

26 – 31 August, Bochum (Germany)

RUHR UNIVERSITÄT BOCHUM RUB

中德科学中心 Chinesisch-Deutsches Zentrum für Wissenschaftsförderung

Harbin Institute of Technology

Content

Welcome

We cordially welcome the delegates of the second Sino-German Symposium on "Material-Oriented Micro/Nano Manufacturing: Modeling, Experiment and Application" in Bochum from 22 to 31 August, 2018. At the same time, we welcome all participates of the Sino-German Summer School, which is held in conjunction with the symposium. Thanks to the success and the very positive feedback after our first symposium in Harbin last year, we are very grateful to be given the chance to continue the meetings on this scientifically and technologically challenging topic and possibly to start a new series of Sino-German Symposia.

Our special thanks go to Eva Masuch for having organized the venue and accommodation and for creating a positive atmosphere for this meeting.

We would like to thank the Sino-German Center for Research Promotion in Beijing for supporting this second Sino-German Symposium and Summer School.

Now, we very much look forward to discussions about advances in material-oriented micro/nano manufacturing of engineers and scientists from different disciplines of mechanical engineering, fabrication technology, and materials science, and we would like to wish all participants an inspiring and fruitful symposium and a summer school full of new insight!

Prof. Dr. Alexander Hartmaier

Interdisciplinary Centre for Advanced Materials Simulation

Ruhr-University Bochum, Germany

Prof. Dr. Junjie Zhang

Center for Precision Engineering

Harbin Institute of Technology, China

Organization

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Prof. Dr. Alexander Hartmaier, Interdisciplinary Centre for Advanced Materials Simulation, Ruhr-University Bochum, Germany

Prof. Dr. Junjie Zhang, Center for Precision Engineering, Harbin Institute of Technology, Harbin, China

Prof. Dr. Zongwei Xu, State Key Laboratory of Precision Measuring Technology and Instruments, Tianjin University, China

Harbin Institute of Technology

RUHR UNIVERSITÄT BOCHUM RUB

Chinesisch-Deutsches Zentrum für Wissenschaftsförderung
中德科学中心

Venue and Accommodation

© Mercure Hotel, Bochum

Mercure Hotel Bochum City
(Right opposite the Bochum central train station)

Massenbergstraße 19-21
44787 Bochum
Germany

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www.mercure-hotel-bochum.de

Symposium venue:

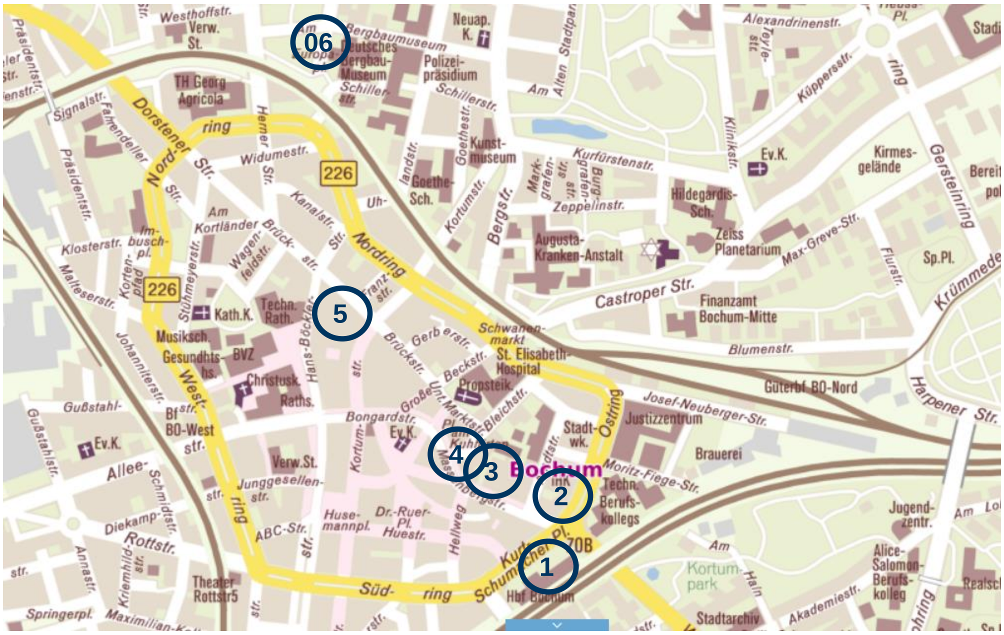
Rooms Dali and Kandinksy, 1st floor.

Accommodation:

According to the Sino-German Center's regulations, twin rooms to share will be provided for Summer School participants and single rooms for Summer School teachers and Symposium delegates.

For self-paying external delegates, single rooms at a reduced conference rate have been reserved.

Overview Bochum city and places



© Stadt Bochum

1) Bochum central railway and subway station
U 35 Campus Linie, direction Ruhr-Universität / Hustadt

2) Mercure Hotel, Massenbergstraße 19 - 21

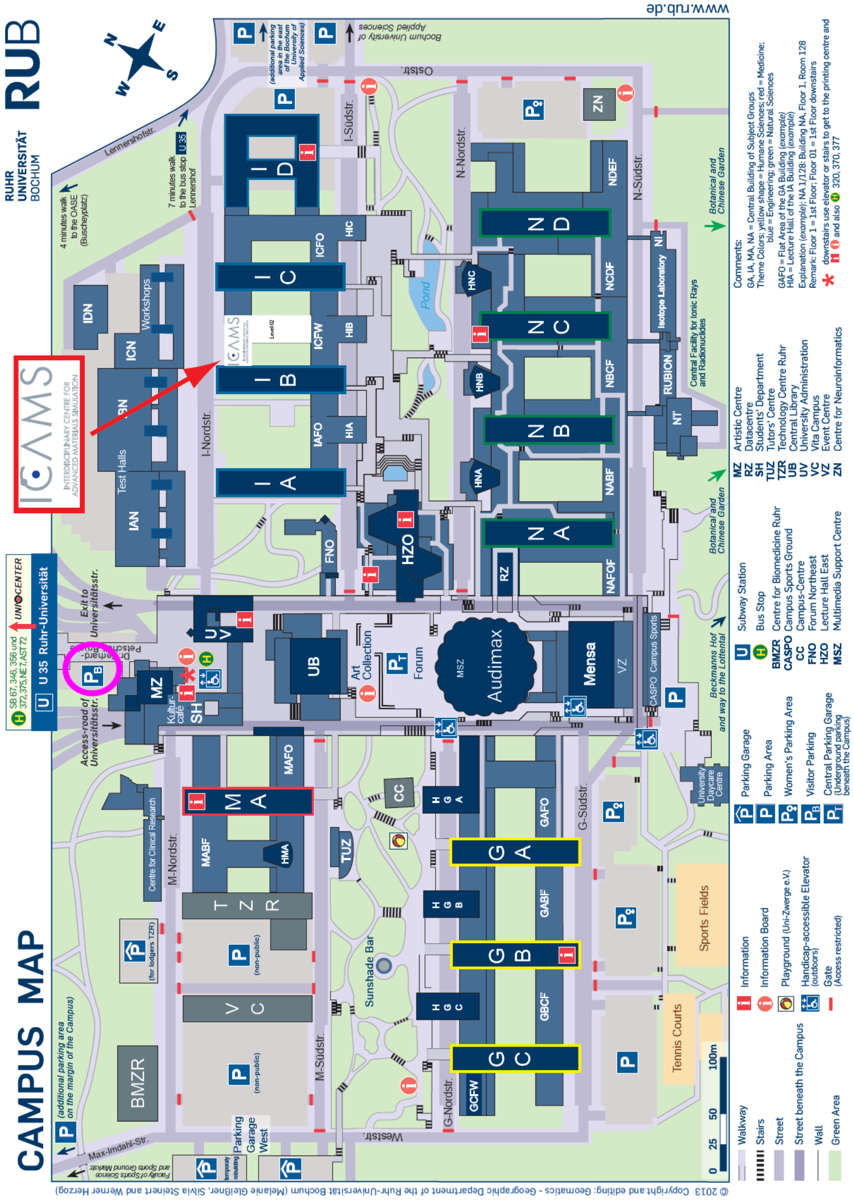
3) Restaurant Yamas (conference dinner on 27 August), Massenbergstr. 1

4) Restaurant Mutter Wittig (dinner on 29 August), Bongardstr. 35

5) Restaurant Paulaner Botschaft (dinner on 30 August), Brückstr. 31

6) Mining Museum (visit on 30 August): From Ruhr-University with subway 35 until stop “Deutsches Bergbaumuseum”, 2 stops after “Bochum Hauptbahnhof (Bochum central station).

Overview Ruhr-Universität Campus



From the campus line stop (U 35 Ruhr-Universität) turn right after climing the stairs and cross the bridge towards the campus, pass the library (UB) on the left side, and turn right behind building HZO. Continue until you reach building ICFW and enter it, take the right corridor and contiunue to its end at which you see the entrance to ICAMS at the opposite slightly left. Should you need help, please call +49 234 3229368 (Eva Masuch).

Symposium Program

26 August Arrival and onsite registration at Mercure Hotel

18:30 Welcome dinner: Mercure Hotel

27 August

09:00 – 09:30 Opening ceremony, welcome by A. Hartmaier and J. Zhang

09:30 – 10:20 **Session I: Micro/Nano scale characterization-I (Alexander Hartmaier)**

1	09:30	**Erica Lilleodden** **Keynote:** Coupled influences of finite volumes and microstructural length-scales on the mechanical response of materials
2	10:00	**Mathias Göken** Deformation Mechanisms at the Nanoscale - From superplastic deformation to thin films

10:20 – 10:40 Cofee break

10:40 – 11:40 **Session I: Micro/Nano scale characterization-II (Shuming Yang)**

3	10:40	**Andreas Rosenkranz** Surface engineering meets material characterization – Improved fundamental understanding by advanced characterization
4	11:00	**Janine Pfetzing-Micklich** Mechanical Characterization on the Microscale
5	11:20	**Qian Liu** Phase-shifting interferometry for in-situ/ on-machine measurement of surface topography

11:40– 13:00 Lunch break

13:00 – 14:20 Session II: Atomistic modeling (Mathias Göken)

1	13:00	**Michael Moseler** Atomistic understanding of superlubric carbon coatings
2	13:20	**Herbert M. Urbassek** Atomistic modeling of solid-state phase transformations in iron
3	13:40	**Arkady Krashenninikov** Optimizing the parameters of ion beams to pattern free-standing and supported two-dimensional materials: insights from atomistic simulations
4	14:00	**Gaobo Xiao** Large scale molecular dynamics simulation of subsurface damage formation in ductile regime machining of silicon carbide

14:20 – 14:40 Coffee break

14:40 – 16:10 Poster Session I: Posters form Summer School participants

18:00 Conference Dinner, Restaurant Yamas, Massenbergstr. 1

28 August

09:00 – 11:00 Session III: Material-oriented applications (Yiting Yu)

1	09:00	**Huigao Duan** Advanced nanofabrication techniques for plasmonic applications
2	09:20	**Tianfeng Zhou** Microstructure manufacturing on the graphene-enhanced nickel-phosphorus composite plating
3	09:40	**Shuming Yang** On-line measurement for nanomanufacturing
4	10:00	**Zhenyu Zhang** Development of novel chemical mechanical polishing slurries used for soft-brittle crystals and alloys
5	10:20	**Chengwei Song** Thermal decomposition processing of polystyrene in water by femtosecond laser irradiation
6	10:40	**Lulu Li** Sub-aperture stitching method based on surf feature matching

11:00 – 11:10 Coffee break

11:10 – 12:10 Round-table discussion on research cooperations

12:10 – 13:30 Lunch break

13:30 – 14:30 Session IV: Tribological properties (Zhenyu Zhang)

1	13:30	**Junjie Zhang** Tribological properties of textured stainless steel by Hauck energy surface processing and diamond cutting
2	13:50	**Petra Wiederkehr** Micromachining of bionic surface structures for tribological optimization of forming processes
3	14:10	**Xinchun Chen** Tribochemical mechanism of graphene as anti-friction solid lubrications

14:30 – 14:45 Coffee break

14:45 – 16:45 Session V: Micro/Nano forming (Jianfeng Xu)

1	14:45	**Olaf Dambon. Speaker: Tim Grunwald** Replicative Manufacturing of Glass Optics with functional Microstructures
2	15:05	**Dong Wu** Femtosecond laser 3D microfabrication and its applications
3	15:25	**Karsten Durst** Metallic Nanoimprinting: Nanoscale surface structuring by confined plastic deformation
4	15:45	**Xichun Luo** Fabrication of functional micro- and nanostructured surfaces by focused ion beam and nanosecond laser
5	16:05	**Yiting Yu** Planar super-oscillation lenses (SOLs): design, fabrication and practical considerations
6	16:25	**Zongwei Xu** Defect engineering of carbon-based functional structures using ion beam nanomachining

16:45– 17:00 Coffee break

17:00 – 18:30 Poster Session II: Posters of Summer School participants

19:00 Dinner: Mercure Hotel

29 August

09:00 – 10:40 Session VI: Material removal process (Herbert Urbassek)

1	09:00	**Lei Chen** Ultimate-precision nanomanufacturing via single atomic layer removal of silicon
2	09:20	**Fabian Pöhl** Deformation behavior and prediction of volume loss of tempering steel under controlled scratch conditions
3	09:40	**Jianfeng Xu** Three-dimensional optical micro-arrays machined by focus ion beam milling
4	10:00	**Jianguo Zhang** Micro/nano machining of difficult-to-cut materials by applying elliptical vibration cutting
5	10:20	**Guo Li** Surface quality evaluation and accuracy control of low density polymer foams in ultra-precision turning

10:40 – 11:00	Coffee break
11:00 – 12:00	Round-table discussions on research cooperations
12:00 – 13:00	Lunch break

13:00 – 14:20 Session VII: Process models (Junjie Zhang)

1	13:00	**Norbert Huber** Modeling of Wear
2	13:20	**Alexander Hartmaier** Micromechanical modeling of metal fatigue
3	13:40	**Julia Kundin** Microstructure simulations of Fe-MnAlC alloy from SLM using phase-field model
4	14:00	**Hamad ul Hassan** On the application of crystal plasticity finite element method approach to the modeling of wear mechanisms

14:20 – 14:40	Coffee break
14:40 – 16:30	Plenary discussion and planning of scientific cooperations
18:00	Dinner: Restaurant Mutter Wittig, Bongardstr. 35

30 August

Morning	Lab tour Ruhr-Universität Bochum
	Lunch in RUB Cafeteria
14:30	Visit of Bochum Mining Museum
17:00	Dinner at Restaurant Paulaner Botschaft, Brückstr. 31

31 August

Departure

Symposium Delegates and Abstracts

S-I-1 KEYNOTE
COUPLED INFLUENCES OF FINITE VOLUMES AND MICROSTRUCTURAL LENGTH-SCALES ON THE MECHANICAL RESPONSE OF MATERIALS

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Prof. Dr. Erica Lilleodden heads the Department for Experimental Mechanics in the Institute for Materials Research, Materials Mechanics at the Helmholtz-Zentrum Geesthacht (HZG) and is Professor for Experimental Micromechanics in the Institute for Advanced Ceramics at the Hamburg University of Technology. She received her Ph.D. in Materials Science & Engineering from Stanford University in 2002. She was a postdoctoral fellow at LBL and a Humboldt fellow at Forschungszentrum Karlsruhe (now KIT) before joining HZG in 2006. In 2012, she was awarded as a top female researcher by the Helmholtz Initiative and Networking Fund with funding for a professorship in the amount of 750 k€. She was elected chair of the 2016 Gordon Research Conference on Thin Film and Small Scale Mechanical Behavior. She currently serves on the EMMCC European Mechanics of Materials Conference Committee and is a member of the Think Tank of the Helmholtz Society. Her research focuses on the mechanisms of deformation and failure in structural materials, with particular interest in the effects of microstructural and geometric length-scales as identified through in situ mechanical investigations within the SEM, TEM and synchrotron beamlines.

Abstract: The nearly universal observation of an indentation size effect (ISE) achieved during indentation into single crystalline metals led to much debate within the materials mechanics community as to why such behavior occurs. A leading theory argues that the gradient in plastic strain inherent to the indentation experiment leads to an increased hardness at the smallest depths. Other models of the ISE include dislocation nucleation or source-limited effects, while still others have argued that the apparent ISE is an artifact associated with sample preparation or inappropriate data analysis. The advent of microcompression testing has served to test some of these theories, where an increase in flow stress with decreasing pillar diameter is widely observed despite no extrinsic gradient in plastic strain. Here, the scaling response of hardness with indentation depth in the case of nanoindentation testing will be compared to that of flow stress with pillar diameter for the case of microcompression testing. Consideration of the imposed strain state and boundary conditions for these two experiments provides insight into the physical basis of the size effects observed. Drawing upon results from nanoindentation and microcompression experiments on a variety of materials, the influence of varying microstructural lengths-scales and Peierls barrier, four prominent models of size effects are explored, with a bias towards the effect of finite volume on the self-organizing nature of dislocation plasticity.

S-I-2
DEFORMATION MECHANISMS AT THE NANOSCALE – FROM SUPERPLASTIC DEFORMATION TO THIN FILMS

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Prof. Dr. Mathias Göken studied physics at the University Münster and did his PhD at the MPI for Iron Research, Düsseldorf in the field of fracture mechanics and in situ AFM observations of dislocation processes at crack tips (PhD approved by RWTH Aachen 1995). From 1996 to 2002, he was group leader for nanomechanics at the University of Saarland. From 1998-1999, he worked with a Feodor-Lynen fellowship in the group of William D. Nix at Stanford University (USA). In 2002, he accepted a full professorship at the Friedrich-Alexander-University Erlangen-Nürnberg, FAU. His track record includes more than 240 publications. The scientific work of Prof.Göken focuses on the mechanical behaviour and microstructure of advanced new materials and coatings and especially on nanocrystalline/ultrafine-grained materials and microforming processes. Research carried out by his group has shown that very interesting lamellar metallic composites (LMCs) can be produced on a large scale by accumulative roll bonding, ARB. These ARB sheets show exceptional properties, i.e. significantly higher strength and improved ductility and fatigue resistance. Nanomechanical testing approaches are developed in the Göken-group, which allow measuring the properties of individual phases and close to interfaces. Furthermore, the properties and microstructure of high temperature materials (Ni-base and Co-base superalloys, TiAl alloys) and superplastic materials are being investigated.

Abstract: Nanomechanical testing allows a fascinating inside into the deformation behavior of materials on the micro- and nanometer scale. Nanoindentation, micro-pillar or in-situ TEM testing are now widely available and allow determining the mechanical properties on a very small scale. With such techniques a new insight into the understanding of the relevant deformation mechanisms as for example dislocation based plastic deformation mechanisms and grain boundary sliding can be gained. Superplastic microforming has a great potential for fabricating MEMS devices or other small-scale objects. However, it has not been clear if the superplastic deformation behaviour subsists at the lowest length scale. For this reason, the strain-rate sensitive deformation behavior of superplastic Zn-22% Al was investigated as a function of the specimen size, using nanoindentation and micropillar compression techniques at room and elevated temperatures. It is found that the superplastic flow behavior breaks down below a critical pillar diameter or plastic zone size although interface shearing is largely found on the pillar surfaces or close to the indents. This phenomenon is discussed based on the rate-controlling deformation processes involving dislocations which lead to this transition.

More detailed observations of the deformation mechanisms are enabled by in situ transmission electron microscopy (TEM) investigations. For this a new flexible method for the preparation of thin film samples for in situ mechanical testing in a TEM has been developed [2], which is based on a combination of focused ion beam (FIB) shadow

milling and electron-beam-assisted etching with Xenon difluoride precursor gas. With this method Cu and nanotwinned Cu-Al thin films were tested in situ in the TEM. Al is an effective element to reduce the stacking fault energy in Cu alloys and leads to increased amount of twinning and detwinning events. The films are tested until final fracture and different deformation mechanism as sliding of grains, twinning and dislocation activity can be correlated with the captured stress-strain curves from the experiment.

References

[1] P. Feldner, B. Merle, and M. Göken, Materials and Design 153 (2018) 71–79

S-I-3

SURFACE ENGINEERING MEETS MATERIAL CHARACTERIZATION – IMPROVED FUNDAMENTAL UNDERSTANDING BY ADVANCED CHARACTERIZATION

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Dr.-Ing. Andreas Rosenkranz is currently Professor of Materials Science (Chair for material-oriented tribology) at Universidad de Chile/Chile in the Department of Chemical Engineering, Biotechnology and Materials Science. Prior to this position, he worked as a postdoctoral researcher at the University of California in San Diego and at the Catholic University in Santiago de Chile. His postdoctoral stay in San Diego was granted by the Alexander von Humboldt Foundation in Germany. In 2015, Dr. Rosenkranz finished his PhD in Materials Science at Saarland University at the Institute for Functional Materials under the supervision of Prof. Dr. Frank Muecklich. The topic of his PhD was related to laser surface patterning and its effect on the resulting tribological behavior under different lubricated conditions. The focus of his research work lies on tribology combined with modern characterization techniques in order to fundamentally investigate tribological problems.

Abstract: Tribology is an interdisciplinary topic involving physics, chemistry, materials science and even biology. In all loaded and moving parts, tribology is essential since it determines energy efficiency, sustainability and reliability. Researchers around the globe have tried to tailor tribological properties by surface engineering (surface patterning and/or coatings) to reduce friction and wear. In order to fabricate well defined surface patterns, various techniques ranging from lithography over micro-coining to laser-based techniques can be used. In this context, laser surface patterning has proved to be a promising approach to generate different pattern geometries with features sizes in the sub-micron range in a fast and efficient way.

Nowadays, it becomes important to understand the material's properties that greatly affect friction and wear. In particular, a detailed study of the surface chemistry as well as the microstructure close to the surface can be very helpful to explain tribological

phenomena. A multi-technique approach including Raman spectroscopy, X-ray photoelectron spectroscopy and atom probe tomography is promising since just one technique cannot quantify the entire surface chemistry on all scales. Regarding microstructure, grain sizes, grain sizes distributions, the crystallographic texture as well as the defect situation need to be studied by focused ion beam microscopy, transmission electron microscopy and electron back scatter diffraction. Moreover, it is worth to investigate the mechanical properties such as hardness on different scales. To fully understand ongoing tribological processes, surface chemistry, microstructure and mechanical properties need to be studied on different scales using a multi-method approach.

S-I-4
MECHANICAL CHARACTERIZATION ON THE MICROSCALE

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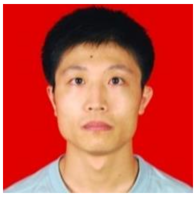
Dr. Janine Pfetzing-Micklich has been manager of the Forschungsbau “Center for Interface Dominated High Performance Materials” (Zentrum für grenzflächendomnierte Höchst-leistungswerkstoffe, ZGH) at Ruhr-Universität Bochum (RUB), Germany, since 2017. From 2015 to 2017 she was scientific assistant of Prof. E. George at the department Materials Design at RUB. Before this, from 2010 to 2014, Dr. Pfetzing was group leader in the field “Mechanical properties of small scale systems” at the department Materials Science and Engineering of Prof. G. Eggeler at RUB. At the same institute, Janine Pfetzing-Micklich received her PhD in 2009 with her dissertation entitled “Nanoindentation of NiTi Shape Memory Alloys.

Abstract: The increasing miniaturization of components in many areas of technology demands for an understanding of mechanical properties in small material volumes. In the last decade, new test methods and sample geometries have been developed which offer new possibilities for local mechanical characterization. The focus of this presentation is to show how different in-situ and ex-situ micromechanical characterization techniques help to gain new insights of mechanical properties. It is shown, how micromechanical experiments can be used to investigate elementary deformation mechanisms on model materials (e.g. gold) and on technologically interesting functional materials (e.g. NiTi shape memory alloys). Results from microshear experiments can characterize the localized plastic deformation with its stochastic nature associated with sudden deformation events. Nanoindentation results from indentation in NiTi shape memory alloys help to understand limiting conditions (e.g. temperature, strain gradient) for functional mechanical behavior on the microscale. High throughput nanoindentation is beneficial in the field of combinatorial materials science. Nanoindentation results can be used for screening the mechanical characteristics with respect to the material composition, which helps to identify new

phases with interesting mechanical properties.

S-I-5

PHASE-SHIFTING INTERFEROMETY FOR IN-SITU/ ON-MACHINE MEASUREMENT OF SURFACE TOPOGRAPHY



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Assoc. Prof. Dr. Qian Liu currently is associate professor at the Institute of Machinery Manufacturing Technology (IMMT), China Academy of Engineering Physics (CAEP). Qian Liu received his BSBSC degree from Beijing Institute of Technology in 2006, and MS, and Ph. D. degrees from CAEP in 2009 and 2015, respectively. His research on phase-shifting interferometry was awarded Excellent Doctoral Dissertation Nomination by China Society for Optical Engineering (CSOE). He has been a researcher in IMMT since 2009 and was promoted to associate professor in 2017. His research interests include metrology, optical microscopy and interferometry. He has four patents and has published more than 30 technical papers.

Abstract: Phase-shifting interferometry (PSI) has widespread application in topography measurement of precisely machined surface, due to its high accuracy and high spatial resolution. When producing phase shifting, the optical path usually changes by tens of nanometers via controlled way. However, the phase shifting process is easily disturbed by mechanical vibration, and phase-shifting error and fringe contrast variation arise. Both the phase-shifting error and fringe contrast variation are significant error sources of PSI. The sensitivity of PSI to environmental vibration hinders its application to in-situ or on-machine measurement. To extend capability of PSI, we develop an iterative method to desensitize PSI to vibration. In the method, the surface phase (height) is solved from a large-scale set of equations, which is constructed with the collected interferograms. And a three-step iterative algorithm is proposed to solve the equation set and some strategies are used to increase the convergence of iteration. The vibration-resistant capabilities of the method was tested under vibration over a large frequency range, and it is indicated that the method is capable of providing accurate measurement result, with RMS error less than 0.02waves (13nm@633nm wavelength) or better. In addition, the method was tested under practical vibration of a finishing machine, and the maximum error of measuring an optical surface is 4.4nm. The presented method provides an effective but low-cost solution for surface measurement with PSI used in-situ or on-machine occasion, and meanwhile ensures a good spatial resolution rather than one-shot interferometry.

S-II-1

Atomistic understanding of superlubric carbon coatiings

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Prof. Dr. Michael Moseler received his diploma and Ph.D. degrees in Physics from the Albert-Ludwigs-University in Freiburg, Germany in 1994 and 1998, respectively. After postdoctoral research at the Georgia Institute of Technology in Atlanta, he became leader of a computational materials science group at the Fraunhofer Institute for Mechanics of Materials in Freiburg in 2002. In addition to this position, he is Professor for Modelling and Simulation of Functional Nanosystems at the Physics department of the Albert-Ludwigs-University in Freiburg. His research activities cover classical molecular dynamics simulations of friction, lubrication and wear processes as well as phase transformations in tribosystems. In addition, he studies tribochemical processes using density functional theory. His previous work covered density functional calculations of finite size effects in free and supported clusters including their catalytic properties. Further activities were in nanofluidics, (e.g. jet formation, capillary impregnation and whetting), melting of nanoparticles, and multiscale models for thin film growth.

Abstract: Superlubricity of tetrahedral amorphous carbon (ta-C) coatings lubricated with unsaturated organic friction modifiers or glycerol is a well-known phenomenon, but the underlying mechanisms remain elusive. Here, combined experiments and simulations unveil a universal tribochemical mechanism leading to superlubricity of ta-C/ta-C tribopairs. Pin-on-disc sliding experiments show that ultra- and superlow friction with negligible wear can be achieved by lubrication with unsaturated fatty acids or glycerol, but not with saturated fatty acids and hydrocarbons. Atomistic simulations reveal that, due to the simultaneous presence of two reactive centers (carboxylic group and C=C double bond), unsaturated fatty acids can concurrently chemisorb on both ta-C surfaces and bridge the tribogap. Sliding-induced mechanical strain triggers a cascade of molecular fragmentation reactions releasing passivating hydroxyl, keto, epoxy, hydrogen and olefinic groups. Similarly, glycerol's three hydroxyl groups react simultaneously with both ta-C surfaces, causing the molecule's complete mechano-chemical fragmentation and formation of aromatic passivation layers with superlow friction.

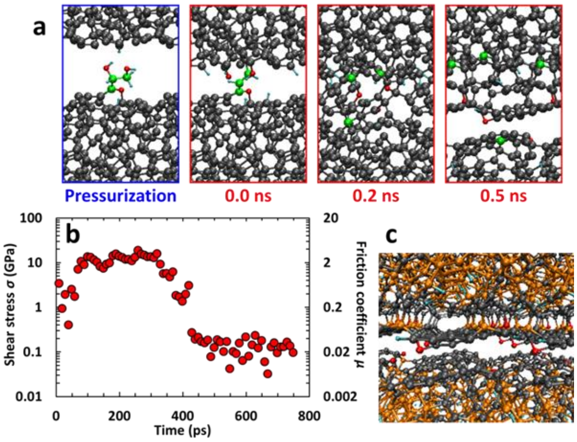

Figure: A QMD simulation of two ta-C surfaces lubricated with a glycerol molecule. (a) Snapshots of the 1-ns sliding simulation. (b) Evolution of the shear stress σ and friction coefficient μ. (c) Shear-induced aromatic passivation of both ta-C surfaces. 3- and 4-fold coordinated C atoms are represented in grey and orange spheres, respectively.

S-II-2

ATOMISTIC MODELING OF SOLID-STATE PHASE TRANSFORMATIONS IN IRON

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Prof. Dr. Herbert M. Urbassek received the Ph.D. degree in theoretical physics from the Technical University of Braunschweig, Germany, in 1983 with a thesis on ion surface interaction. He won the Gaede Award of the German Vacuum Society in 1990 and was awarded a Heisenberg fellowship from 1990–2. In 1993, he joined the physics faculty of the University of Kaiserslautern, Germany. He held several research positions in Germany, Spain, Denmark and the US. Currently, he is actively involved in two Collaborative research Centers and an International Research Training Group, jointly with the University of California, of the German Research Council. His research interests presently focus on computational materials science including materials relevant for mechanical engineering, for planetary science and biophysics.

Abstract: The phase diagram of iron features the notorious and technologically relevant transformation between the low-temperature α-phase (bcc) and the high-temperature γ-phase (fcc). We present an overview of interatomic interaction potentials which are able to describe this transformation. Techniques for calculating the thermodynamics (free-energy differences) and kinetics (temporal evolution) of the transition are presented. Atomistic simulation provides insights into the pathways of the transformation as the atomic re-ordering is easily followed. Also the orientation relationship along phase boundaries are easily determined. Defects – such as free surfaces, grain or phase boundaries – influence the transformation, as does any stress or strain exerted on the specimen. These influences can be analyzed using atomistic simulation.

S-II-3
OPTIMIZING THE PARAMETERS OF ION BEAMS TO PATTERN FREE-STANDING AND SUPPORTED TWO-DIMENSIONAL MATERIALS: INSIGHTS FROM ATOMISTIC SIMULATIONS

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Dr. Arkady Krasheninnikov is a group leader at the Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Germany, and a guest/visiting professor at Danish Technical University and Aalto University, Finland. He received his PhD degree in 1995 from the Moscow State Engineering Physics Institute, Russia. His current scientific interests include various areas of computational materials science, electronic structure calculations, two-dimensional materials, and irradiation effects in solids. For his work on defects in two-dimensional systems, he was awarded the 2017 HZDR Research Prize. His other recognitions include the 2017 Highly Cited Researcher by Clarivate Analytics (Web of Science) and the Outstanding Referee title from the American Physical Society (2018). Throughout his career, he has organized about 20 international conferences in workshops, including symposia at meeting of the Materials Research Society and The European Materials Research Society.

Abstract: Ion irradiation has successfully been used for introducing impurities and creating defects in two-dimensional (2D) materials in a controllable manner. Moreover, focused ion beams, especially when combined with in-situ or post-irradiation chemical treatments, can be employed for patterning and even cutting 2D systems with a high spatial resolution. The optimization of this process requires the complete microscopic understanding of the interaction of energetic ions with the low-dimensional targets. In my presentation, I will dwell upon the multi-scale atomistic computer simulations of the impacts of ions onto free-standing (e.g., suspended on a TEM grid) and supported (deposited on various substrate) 2D materials, including graphene and transition metal dichalcogenides, such as MoS_2 and WS_2. The theoretical results will be augmented by the experimental data obtained by the coworkers. Specifically, I will touch upon production of defects in the supported graphene and 2D MoS_2, and demonstrate that depending on ion mass and energy, the defect production can be dominated by direct ion impacts, back scattered ions or atoms sputtered from the substrate. I will also address the response of graphene on metal (Ir) substrates to ion irradiation and show how strong interaction of defects in graphene with the substrate can be used for engineering a graphene-based nanomesh.

S-II-4

LARGE SCALE MOLECULAR DYNAMICS SIMULATION OF SUBSURFACE DAMAGE FORMATION IN DUCTILE REGIME MACHINING OF SILICON CARBIDE

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Abstract: Large scale molecular dynamics modelling is conducted to study the formation and propagation of subsurface cracks in the ductile regime machining of single crystal silicon carbide. Two types of machining, i.e. abrasive machining and orthogonal cutting, are investigated. The modelling results show that for both types of machining subsurface cracks can be formed even in the ductile mode machining, and consequently affect the surface integrity of the machined surface. A series of depth of cut is adopted for the orthogonal cutting simulations, and the brittle-ductile cutting mode transition is reproduced. The critical depth of cut is compared with the experimental value in plunge cutting, and good consistence is observed.

S-III-1

ADVANCED NANOFABRICATION TECHNIQUES FOR PLASMONIC APPLICATIONS

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Abstract: Nanofabrication is the key enabling technique for fundamental researches and applications of plasmonics. Advanced fabrication strategies with enhanced resolution and reliability may greatly benefit the plasmonics research field. Top-down fabrication methods based on electron-beam lithography and focused ion beam are currently dominant in plasmonics research field due to their reliability and flexibility to fabricate arbitrary geometries. However, due to the challenges of low throughput, limited resolution at the sub-10-nm scale and inability to produce high-quality-factor resonant structures, the existing top-down fabrication processes still cannot satisfy the requirements of plasmonics in practice. In the past years, based on sub-10-nm electron-beam lithography, we have demonstrated reliable fabrication of strongly-coupled plasmonic structures for fundamental study, plasmon-enhanced spectroscopy and color printing. In this talk, we report our recent efforts and progress on pushing the limit and extending the capability of top-down fabrication methods for plasmonics. With the newly developed processes, we show that multiscale and hierarchical plasmonic structures could be reliably fabricated and replicated over large area. These structures, which were impossible to fabricate before, hold the promise for various applications in surface-enhanced spectroscopy, new-concept high-resolution full-color printing and hot electron devices.

S-III-2

MICROSTRUCTURE MANUFACTURING ON THE GRAPHENE-ENHANCED NICKEL-PHOSPHORUS COMPOSITE PLATING

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Abstract: To improve the mechanical properties of nickel-phosphorus (Ni-P) mold material for glass molding, an ultrasonic-assisted electroless plating method is proposed for the synthesis of graphene-enhanced nickel-phosphorus (G-Ni-P) composite films on heat-resistant stainless steel (06Cr25Ni20). Graphene flakes are prepared by an electrochemical exfoliation method. The Vickers hardness and Young's modulus of the G-Ni-P composite are increased by 8.0% and 8.2% compared with the values of Ni-P, respectively. The fabrication of microstructures on the G-Ni-P mold material with enhanced mechanical properties is studied by comparing with the Ni-P counterpart, which shows promising characteristics for the mold manufacture.

S-III-3
ON-LINE MEASUREMENT FOR NANOMANUFACTURING

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Abstract: On-line measurement is important for manufacturing particularly precision manufacturing and nanomanufacturing. The critical requirements of on-line measurement include reliable performance, compact, flexible, independence on environment etc. For the case, we have done exploration research on nano-materials, nano-devices and systems for measurement. Basically, we have developed techniques for different types of nanowire, nanowire array, core/shell nanowire as well as graphene, graphene oxide, carbon fiber etc. And then we have used these materials to make devices and measurement systems facing for nano-scale on-line measurement application to nanomanufacturing.

S-III-4
DEVELOPMENT OF NOVEL CHEMICAL MECHANICAL POLISHING SLURRIES USED FOR SOFT-BRITTLE CRYSTALS AND ALLOYS

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Abstract: Strong acids, alkalis and toxic chemical reagents are usually used in the chemical mechanical polishing (CMP) for soft-brittle crystals and alloys, aiming to obtain ultra-smooth and low damage surfaces. This has great potentials of dangers for both environment and operators. To overcome the disadvantages of traditional CMP slurries, novel environment-friendly CMP ones are developed, consisting of mainly hydrogen peroxide, silica, malic and citric acids. The surface roughness Ra is less than 1 nm after CMP on the polished surfaces of soft-brittle crystals and alloys. Ultra-smooth and low damage surfaces are obtained by the developed CMP slurries. The fundamental mechanisms of CMP for novel CMP slurries are investigated using electrochemical measurements and X-ray photoelectron spectroscopy.

Reaction equations are proposed for soft-brittle crystals and alloys in CMP, according to the experimental and measurement results.

S-III-5

THERMAL DECOMPOSITION PROCESSING OF POLYSTYRENE IN WATER BY FEMTOSECOND LASER IRRADIATION

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Abstract: The interaction process between femtosecond laser and polymer is extremely complex, and is difficult to observe directly. This process is difficult to be simulated, too, due to it be limitted by mastered mechanism and computer power currently. In this paper, the experimental research was carried out, which polystyrene in water was ablated by focused femtosecond laser, and the ablation products that come from this experiment was collected. The molecular structures of varied component that make up of the ablation products were analyzed, and were used to inferred the interaction process between femtosecond laser and polystyrene. The main molecular structure of solid products is the open benzene rings. This result shows the benzene ring and carbon in main chain absorb laser differently, which can introduce the change of organic ingredients of surface and ablation products. In the analyzing of ablation mechanism, there is a condition in which the benzene ring absorb energy but not dissociates. To analysis the impact of energy to materials, we simulated this condition with lammps, a molecular dynamics simulation software.The bonds changing in simulation shows the results which energy is applied to benzene ring is same to the thermal dissociation caused by heating materials in same power. This result can match up with the experiments result and the theory inference. A feasible methodology is offered to predict the interaction mechanism between femtosecond laser and polymer.

S-III-6
SUB-APERTURE STITCHING METHOD BASED ON SURF FEATURE MATCHING

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Abstract: In the process of sub-aperture stitching, the sub-aperture overlap regions are often inaccurately positioned due to positioning error, straightness error and backlash error of the displacement device. The positioning error will not only affect the surface accuracy of the overlap regions, but also be added to subsequent calculations, causing cumulative surface shape errors. In this paper, the sub-aperture stitching method based on Speed-Up Robust Feature (SURF) feature matching is proposed. Using SURF feature matching algorithm, the relative displacements of adjacent sub-apertures are calculated accurately, and the subsequent stitching is performed according to the matching calculation results. This method can reduce the dependence on the precision of the mechanical device of the sub-aperture stitching, and the experiment proves the feasibility.

S IV-1
TRIBOLOGICAL PROPERTIES OF TEXTURED STAINLESS STEEL BY HAUCK ENERGY SURFACE PROCESSING AND DIAMOND CUTTING

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has acted as a senior member of the Chinese Mechanical Engineering Society. Dr. Junjie Zhang has a background in mechanical engineering and computational materials science. His current research interests are focused on material-oriented fundamental and process of ultra-precision machining, micro/nano fabrication of functional surface textures, computational nanomechanics.

Abstract: Surface texturing is a promising approach to reduce friction and wear between rubbing surfaces in mechanical components. Different fabrication methods lead to different texture morphologies as well as sub-surface changes, which consequently influence the effectiveness of the surface texture in terms of friction reduction. In the present work, surface textures with features in the micron scale were fabricated on stainless steel by Hauck energy surface processing and diamond cutting. The mechanical properties of untextured and textured surfaces prepared by those techniques are investigated by indentation tests. Sub-surface changes are examined by cross-sectional SEM analysis. Subsequent ball-on-disc tests indicate that the presence of the surface textures significantly lowers friction and wear compared to untextured samples. It is found that the tribological properties are greatly influenced by the mechanical properties and the sub-surface microstructure.

S IV-2

MICROMACHINING OF BIONIC SURFACE STRUCTURES FOR TRIBOLOGICAL OPTIMIZATION OF FORMING PROCESSES

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Abstract: The increase of functional requirements on technical surfaces, e.g. of moulds and dies for sheet-bulk metal forming, require a continuous optimization of the design of forming tools. Especially the filling of the filigree form elements in this forming process is a major challenge. In addition to conventional coating systems, microstructures can be applied in order to adapt the tribological characteristics of the tool surface and, therewith, to control the material flow. Due to the microscopic dimensions of a single structural element, the production of these structures is mainly

investigated by laser ablation and erosion processes, since these processes provide a sufficient precision. Micromachining of such structures has hardly been researched. However, this manufacturing process offers a number of advantages which favour the use of this process for structuring components. In addition to a high surface quality, it is also possible to achieve a considerably higher ablation rate, which results in a significantly shorter process time. Furthermore, a low process temperature prevents a thermal influence of the subsurface, which avoids negative effects on the technical properties of the microstructure. This presentation shows a selection of bionic microstructures, which are derived from highly resistant surfaces which can be found in nature. In addition to the structural design, the manufacturing process and the influence of the structures on the material flow are also discussed.

S-IV-3

TRIBOCHEMICAL MECHANISM OF GRAPHENE AS ANTI-FRICTION SOLID LUBRICATIONS

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Abstract: Graphene as solid lubricants has been investigated intensively for their potential to provide ultralow friction. The state of low friction of graphene-based lubricants is generally dependent on the structural transformation under sliding tribo-contact. In this work, we present some peculiar findings regarding the evolution of anti-friction interfacial nanostructures in different materials systems. The results clarify that the critical issue for graphene lubrication is the maintenance of layered structures for graphene in the tribochemical processes. And the anti-friction performances are the outcomes of synergetic combinations of graphene and other carbon nanostructures. These findings deepen the understanding of graphene lubrication mechanisms and enable a more effective design of carbon-based 2D solid lubricants.

S-V-1

REPLICATIVE MANUFACTURING OF GLASS OPTICS WITH FUNCTIONAL MICROSTRUCTURES

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Abstract: Microstructuring of glass optics enables a large variety of benefits for miscellaneous fields of application. From an enhancement of the perfomance of optical systems to the haptic improvement of coverglasses – the advantages of structured glass are obvious. Nevertheless, an efficient production of the structured components is the key to success for applications aside science and research. The technology Precision Glass Molding is able to combine the contradicting aspects of high precision and high volume production. Precision Glass Molding is a replicative manufacturing method that brings the time- and effortful shape generation forward to precise molding tools. In between them, dedicated glass preforms are molded under thermal and mechanical load into the desired shape. The presentation focuses on the mold manufacturing including the microstructuring thereof, the molding itself and the fields of application for the generated optical components

S-V-2
FEMTOSECOND LASER 3D MICROFABRICATION AND ITS APPLICATIONS

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Abstract: Femtosecond laser induced two-photon polymerization (TPP) has been proved to be a powerful microfabrication technique with high efficiency and quality. However, the main drawback of TPP technique is its low fabrication efficiency caused by the point-to-point raster scanning strategy, which seriously restricts its applications. In order to overcome the disadvantages, SLM-based (spatial light modulator) mutlifoci parallel microfabrication and single-exposure fabrication of a certain structures were proposed to significantly speed up the fabrication process, and has a wide range of applications in optics, micromachines, and biology, owing to its capability to dynamically update the intensity distributions in the focal plane by modifying the phase of incident light. A series of 2D-3D functional microdevices such as Damman grating, microfilter and flower-like microtube arrays were rapidly fabricated and show various functions, such as beam splitting, particles filtering and cell manipulation.

S-V-3

METALLIC NANOIMPRINTING: NANOSCALE SURFACE STRUCTURING BY CONFINED PLASTIC DEFORMATION

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Abstract: In this presentation, a new metallic nanoimprinting process is presented, which allows the surface structuring on the micro and nanometer size range. Nanoscale surface structures of metals promises new functional properties like an enhanced heat transfer, reduced friction or super hydrophobic surfaces. Surface structuring relies often on a direct structuring of the materials by methods like femtosecond laser processing, electrolytic processing or lithographic methods. Nanoimprinting however uses a structured die, which is pressed onto the surface and local plastic deformation yields the surface structure. The flow behavior of metals on the nanoscale, is not fully understood.

In this work, a scale bridging experimental approach is used to explore the flow behavior of metals and alloys with different microstructure and work hardening behavior. Used as forming tools are flat punch diamond indenter, with diameters ranging from 100 µm – 5 µm and structure sizes between 15 µm down to 50 nm. This punches are pressed onto different Cu alloys and Ni with grain sizes in between 100 µm down to the nanocrystalline regime. The nanoscale surface structures where analysed with a confocal laser microscope with regard to extrusion height and mould filling. In the presentation, the flow mechanism will be discussed at different length scales, where it is found that both, the work hardening behaviour and the grain size influence the structure formation on the nanoscale.

S-V-4

FABRICATION OF FUNCTIONAL MICRO AND NANOSTRUCTURED SURFACES BY FOCUSED ION BEAM AND NANOSECOND LASER

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Abstract: The first half of the talk introduces focused ion beam machining technique and deterministic modelling and simulation study for the fabrication of high-precision functional plasmonic nanostructures, nanodots for data storage and microgrooves for prolong tool wear. The second half of the talk will introduce a nanosecond laser machining process developed to improve the hydrophobicity of AISI 316L stainless steel surface. A geometrical model of laser machined Gaussian micro hole, together with constrain conditions, was firstly established to predict surface contact angle and optimize structure geometries for maximizing its hydrophobicity. The effects of processing laser power and pitch of microstructures on the topography of the machined surface were investigated through laser machining experiment. This study shows that large ten-point height of surface topography, Sz is an essential condition to form the stable and robust Cassie–Baxter state, i.e. a condition to achieve super hydrophobicity. The comparison between the predicted and measured contact angles in experiments shows that the proposed model can accurately predict contact angle and optimize the geometries of the microstructure to achieve maximum hydrophobicity.

S-V-5
PLANAR SUPER-OSCILLATION LENSES (SOLS): DESIGN, FABRICATION AND PRACTICAL CONSIDERATIONS

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Abstract: Planar metalenses are becoming a research hotspot, showing great potentials for the next-generation highly integrated optoelectronic imaging systems. They possess the extraordinary capability to define the desired focusing optical field with a better flexibility by the subwavelength nanostructures. However, the conventional wavefront design of metalenses sets the barrier to efficiently overcome the diffraction limit, as well as the difficulty to mass produce the centermeter-sized metalenses. In this talk, we will introduce our recent progress in realizing the far-field superfocusing planar metalenses, employing the super-oscillatory theory so that a sub-diffraction-limit focus can be realized without the contribution of evanescent waves. A multi-objective and multi-constraint optimization design method will be presented, which can be used to achieve various superfocusing optical fields as needed. Furthermore, the practical considerations, e.g. achromatism, large-sized lens design, batch fabrication, and so on, are taken into account, aiming for some typical applications.

S-V-6
DEFECT ENGINEERING OF CARBON-BASED FUNCTIONAL STRUCTURES USING ION BEAM NANOMACHINING

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Abstract: Defect engineering has attracted much attention in seeking better materials and functional structures since lattice defects can play a crucial role in controlling the performance. Ion beam machining is one of important fabrication methods in the defect engineering field. However, there are still many challenges in the defect engineering of carbon-based functional structures using ion beam nanomachining. P-type doped 4H-SiC with very low resistivity is still one challenging technology in semiconducting fields. Heavy doping would induce high density of defects in 4H-SiC, which will prevent the decrease of wafer resistivity. Points defect can form the color centers in substrates of diamond and silicon carbide, which can show excellent properties such as single-photon emission, long spin-coherence time even at room temperature, and prospects for large-scale quantum engineering. However, the fabrication efficiency and repeatability for point defects in predetermined locations are still very much low. In this talk, methods of Focused Ion Beam (FIB) nanofabrication, Molecular Dynamics (MD) simulation, Raman characterization, and Sheet resistance measurement were used for the studies carbon-based functional structures' fabrication, including Al ion implanted to 4H-SiC and color center in Diamond. The defects evolution of ions implantation will be discussed basing on the MD analyses, including, thermal spike, different implantation parameters and annealing setups, etc. Raman spectroscopy was conducted to characterize the p-type 4H-SiC with Al concentration ranging from $5 \cdot 10^{16}$ cm^{-3} to $5 \cdot 10^{19}$ cm^{-3}, annealing temperature of 1700°C, 1800°C, 1900°C. The spectroscopic characterization results can

effective analyze the ion implant induced defects for different fabrication conditions.

S-VI-1
ULTIMATE-PRECISION NANOMANUFACTURING VIA SINGLE ATOMIC LAYER REMOVAL OF SILICON

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Abstract: Ultra-precision of nanomanufacturing process down to the atomic level is of paramount importance for new development of nanoelectronics with unique functionalities. The ultimate precision that can be achieved on the crystalline lattice would be the topographic control down to a single atomic layer. Achieving such an ultimate precision requires physical means or processes to reliably and reproducibly remove atomic layers at a specific location with an arbitrary shape without causing subsurface damages or disorders. Here, we demonstrate a mask-less and chemical-free nanolithography process for regio-specific removal of atomic layers on a single crystalline silicon surface via shear-induced mechanochemical reactions of the surface atoms with water molecules. Since the chemical reactions involve only the topmost atomic layer exposed at the interface, removal of the single atomic layer is possible and the crystalline lattice beneath the processed area remains intact, keeping perfect crystalline order without subsurface structural damage. Molecular dynamics simulations were used to explain the atom-by-atom removal process, where the first atomic layer is removed preferentially through the formation and dissociation of interfacial bridge bonds. Based on the parametric thresholds needed for single atomic layer removal, the critical energy barrier for water-assisted mechanochemical dissociation of Si-Si bonds is determined. The mechanochemical nanolithography method demonstrated here could be extended to nanofabrication of other crystalline materials.

S-VI-2
DEFORMATION BEHAVIOR AND PREDICTION OF VOLUME LOSS OF TEMPERING STEEL UNDER CONTROLLED SCRATCH CONDITIONS

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Abstract: During abrasion and machining of steels, the material undergoes locally complex deformation processes. This includes elasto-plastic deformation and the evolution of damage with the result of volume loss, which is undesired in the case of abrasion and desired in the case of machining. Both cases have in common that the deformation behavior and thus the volume loss is system dependent and the prediction based on simple material parameters is not possible. One opportunity to better understand the occurring deformation processes and to estimate the resistance of the material against abrasion and machining are controlled single scratch tests. This study investigates the deformation behavior under single scratch load of tempering steel in different heat treatment conditions. Based on the analysis and quantification of the local deformation behavior and the characterization of the local mechanical properties by nanoindentation an idealized model for the prediction of volume loss is proposed and applied to different additional tempering steels.

S-VI-3
THREE-DIMENSIONAL OPTICAL MICRO-ARRAYS MACHINED BY FOCUS ION BEAM MILLING

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Abstract: Focus ion beam (FIB) has the advantages of high resolution, direct writing without etching mask, and complex-shape fabrication capability when compared to lithography technique. FIB is a promising micro- and nano-machining technology in the manufacturing of three-dimensional optical microstructures. In this study, we discussed the machining parameters of FIB for the designed three-dimensional optical micro-arrays. The effect of ion beam size, dwell time, and overlap of the ion beam on the shape accuracy of the micro-arrays was simulated and experimentally investigated. In addition, several micrometer scale spherical and aspherical surfaces with the surface figure accuracy of tens of nanometers and the surface roughness of about 2 nm were fabricated on a silicon substate. This kind of optical micro-arrays has an excellent application prospect in integrated and miniaturized optical systems.

S-VI-4

MICRO/NANO MACHINING OF DIFFICULT-TO-CUT MATERIALS BY APPLYING ELLIPTICAL VIBRATION CUTTING

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Abstract: Textured surfaces with sophisticated micro/nano structures can provide interesting and advanced functions. Nowadays, elliptical vibration cutting (EVC) is

attracting more and more attentions due to its excellent machining performances in micro/nano machining of difficult-to-cut materials. By applying single crystal diamond (SCD) tools, ultraprecision texturing of ferrous metals and hard-brittle materials, such as hardened steel, tungsten carbide and single crystal silicon, were carried out by applying EVC. Both the excellent machined surface quality and the high machining accuracy can be guaranteed with this novel method. A series of functional surfaces with sophisticated micro/nano structures were successfully fabricated, which can be applied to the molding, encoder, optoelectronics and semiconductor industries. The EVC technology is expected to promote the development of micro/nano machining process in the actual advanced industrial applications.

S-VI-5

SURFACE QUALITY EVALUATION AND ACCURACY CONTROL OF LOW DENSITY POLYMER FOAMS IN ULTRA-PRECISION TURNING

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Abstract: The low density polymer foams play an important role in the laser fusion research, which is the preferred dielectric material and support material in physical experiments. Owing to the irregular micro pore structures on machined foam surface, the conventional technical indicators such as surface roughness and accuracy cannot be used to evaluate the surface quality of machined foam, which reduces the accuracy of foam parts. By means of the SEM and digital image processing technology, the surface porosity is introduced to evaluate the surface quality of foam material. Taking the surface porosity variety of machined foam as the optimization goal, the process parameter optimization model of diamond turning is built, and the optimal process parameters are obtained. The foam machining experiments are carried out on ultra-precision turning. The experimental results show that the size consistency of foam parts is better than 5□m, which verifies the validity of the above method and satisfies the requirements of physical experiments.

S-VII-1
MODELING OF WEAR

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Abstract: The efficiency of micromechanical systems with movable components, such as micro-pumps, micro-turbines, micro-engines or micropositioning devices, is considerably limited by the tribological performance of the mated materials. High friction coefficients reduce the efficiency, while adhesion or capillary forces can exceed the externally applied forces and thereby prevent operation of microsystems due to stiction under unfavourable environmental conditions. For the prediction of wear, the contact pressure and slip can be computed for a given geometry using the finite element method. But the time and position dependent calculation of wear is a challenging problem, when the change of the surface contour is significantly changing. The proposed approach is based on the application of a finite element based wear simulation tool, the Wear-Processor, to simulate wear in time dependent contacts. The Wear-Processor has to bridge the time scales between the very fast pass of a contact over a surface point and the long-term wear simulation that is required for a prediction of the component life. For each potential contacting node, the pressure and slip rate are integrated over time. To this end, computationally efficient incremental implementation of Archard's wear model is applied. The wear coefficients used in this work were identified from pin-on-disc experiments interpreted by the Global Incremental Wear Model. This model efficiently mimics the changing geometry of a spherical pin in the pin-on-disc experiment and allows for a physically meaningful analysis of the wear rate

in dependence of the contact pressure and slip distance. As applications, predictions of wear in a micro gear and in a micro lobe pump are presented.

S-VII-2
MICROMECHANICAL MODELING OF METAL FATIGUE

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Abstract: During high-cycle fatigue fatigue od metals, a large portion of the lifetime of a material is spent in the crack initiation phase. Although macroscopically mostly or even purely elastic material behavior is observed, locally small-scale plastic yielding can occur in regions of increased internal stresses. During such local reversed plastic deformation, damage caused by irreversible dislocation slip accumulates and finally leads to the nucleation of a crack-like defect, which is smaller than the grain size. Such microstructurally short cracks can grow and finally cause the failure of the material. Thus, it is important to understand and properly model the mechanisms and criteria for crack initiation, which are strongly influenced by accumulation of irreversible deformation.

In this work, micromechanical modeling is applied to predict crack initiation within a realistic microstructure. The micromechanical method is based on three main constituents: (i) generation of material microstructures in form of representative volume elements (RVE) (ii) implementation of a crystal plasticity model capturing the relevant mechanisms of cyclic plastic deformation, and (iii) definition of a reliable fatigue

indicator parameter that describes the damage evolution during cyclic deformation. All these steps need to be validated against experiment to allow us to study fatigue crack initiation and the early stages of short crack growth. In this paper, the background of micromechanical fatigue models is introduced and the method is applied to study fatigue behavior and to predict S-N curves and lifetimes of polycrystalline microstructures.

S-VII-3
MICROSTRUCTURE SIMULATIONS OF FE-MNAIC ALLOY FROM SLM USING PHASE-FIELD MODEL

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Abstract: In selective laser melting (SLM), the layer-wise melting with high solidification rate leads to anisotropic microstructures which depend on the laser power and scanning speed. In this study, the microstructure evolution in a Fe-Mn-Al-C alloy fabricated by SLM was simulated by means of the multicomponent phase-field model of the solidification to define the main microstructure characteristic, such as the secondary dendrite arm spacing (SDAS), as well as the component distribution perpendicular to the build direction. The dendrite arms are formed due to the thermal noise added in the phase-field equation. After some coarsening process the distance between dendrite arms tends to a stable constant value. Our results show a good agreement with the experimental data. The model can predict very precisely the SDAS and the components distribution for different process conditions, the laser power and the scanning speed by SLM. Furthermore, it can predict the growth velocity during the solidification of multicomponent alloys as well as a mean growth velocity.

S-VII-4
ON THE APPLICATION OF CRYSTAL PLASTICITY FINITE ELEMENT METHOD APPROACH TO THE MODELING OF WEAR MECHANISMS

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Abstract: In the scope of this work, crystal plasticity (CP) modeling approach coupled with finite element method (FEM) has been developed to study wear behavior of crystalline materials. Johnson-Cook damage model is implemented in the crystal plasticity model including temperature and strain rate effects and the separation of material is realized using element deletion technique for FEM based simulations. A series of parametric studies is performed for different process parameters like depth of cut and tool rake angle for single crystal. The global results like tool reaction force, shape of the formed chip and numerical efficiency are compared for different models. The local results like stress and strain-distribution at the tool tip are also compared for different cases. In the next step, simulations are performed for polycrystals. The findings show that the CP-FEM method can be successfully applied to study and understand different mechanism of wear.

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P-1
INDENTATION INDUCED SUBSURFACE DAMAGE OF METAL-BASED MATERIALS REVEALED BY ATOMIC SIMULATIONS

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Abstract: The properties of multi-crystalline Si are known to alter significantly due to the segregation of impurity atoms at Si grain boundaries (GB). Here, in the present work we studied the interplay between asymmetric grain boundary core and its corresponding local strain state to explain the recent experimental observations of line segregation at Si faceted grain boundaries [1]. Firstly, we developed an interatomic potential for Si, C and Si-C and benchmarked with density functional theory (DFT) calculations for well-known physical properties, solute segregation at flat and faceted grain boundaries, and constructed Wulff diagram [2-4]. Based on the calculations, we will explain the interplay between GB geometries of C segregation with corresponding strain state. Furthermore, the energetics of faceted grain boundaries will be compared with the analytical and Continuum model of faceted GB energetics [5-6].

P-2
STUDY ON THE PROPERTIES OF PSEUDOSPARK-BASED ELECTRON BEAMS IN ELECTRON BEAM SURFACE TREATMENT

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Abstract: In this work, the development of pseudospark discharge in the pre-discharge and hollow cathode phases in a single-gap device are investigated by a time-dependent model to calculate the temporal development of total ionization cross section in varying times and regions. The simulations in our work are performed using the two-dimensional kinetic plasma simulation code XOOPIC. The time-dependent evolutions of the ionization cross section in pre-discharge and hollow cathode phases are presented under varying electric fields and hollow cathode configurations. Thus the electron multiplications and plasma generation processes by ionizing collisions in varying phases are examined and their dependences on a variety of external parameters are determined in different regions in the pseudospark device. The discharge formation time shows highest dependences on the cathode aperture diameters and anode voltages. Additionally, a linear dependence of the pseudospark breakdown time on the time-averaged ionization cross section is illustrated under varying external parameters.

P-3

INDENTATION INDUCED SUBSURFACE DAMAGE OF METAL-BASED MATERIALS REVEALED BY ATOMIC SIMULATIONS

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Abstract: The plastic deformation mechanisms of Cu/Ag multilayers and CuZrTiAlNi high entropy alloys (HEAs) are investigated by molecular dynamics (MD) simulation during the nanoindentation process, in terms of shear strain, indentation force, and surface morphology as well as radial distribution function (RDF). The indentation result of Cu/Ag multilayers shows that due to the interface barrier, the dislocations pile-up at the interface and then the plastic deformation of the Ag matrix occurs due to the nucleation and emission of dislocations from the interface mainly, as well as the dislocation propagation through the interface. It is found that the dislocation pile-up at the interface is determined by the obstruction of the mismatch dislocation network and the attraction of the image force. In addition, the incipient plastic deformation of Cu/Ag multilayers is postponed, compared with that of bulk single-crystal Cu. For CuZrTiAlNi HEAs, the symmetrical distribution of atomic displacement reveals the isotropic of HEA after the indentation treatment. In the deformation region, the Al element would lead to the serious fluctuation in the first peak of RDF, which is much stronger than the other elements. The severe distortion from the atomic size difference maybe reduce the activation energy to the occurrence of shear deformation in HEA, leading to the

transition from brittle to ductile observed by the whole sliding of the local atom group. By means of MD simulation, this effective strategy is used to accelerate the discovery of excellent mechanical properties, and to understand the fundamental nanoindentation responses in advanced multilayers and HEAs.

P-4
IN SITU TEM OBSERVATION OF REBONDING ON FRACTURED SILICON CARBIDE

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Abstract: Silicon carbide (SiC) is widely used in harsh environments and under extreme conditions, including at high-power, high-temperature, high-current, high-voltage and high-frequency. The rebonding and self-matching of stack faults (SFs) is highly desirable to avoid catastrophic failure for SiC devices, especially for specific applications in the aerospace and nuclear power industries. In this study, a novel approach was developed using an eyebrow hair to pick up and transfer nanowires (NWs), in order to obtain in situ transmission electron microscope (TEM) images of the rebonding and self-matching of SFs at atomic resolution. During rebonding and healing, the electron beam was shut off. Rebonding on the fractured surfaces of monocrystalline and amorphous SiC NWs was observed by in situ TEM at room temperature. The fracture strength was 1.7 GPa after crack-healing, restoring 12.9% of that of a single crystal NW. Partial recrystallization along the <111> orientation and the self-matching of SFs are responsible for the rebonding of the monocrystalline NW. In comparison, the fracture strengths were 6.7 and 5.5 GPa for the first and second rebonding, respectively recovering 67% and 55% of that of an amorphous NW. Atomic diffusion contributed enormously to the rebonding on fractured surfaces of an amorphous NW, resulting in a healed surface consisting of an amorphous phase and crystallites. This rebonding function provides new insight into the fabrication of high-performance SiC devices for the aerospace, optoelectronic and semiconductor industries.

P-5
TAILORING SURFACE QUALITY THROUGH MASS AND MOMENTUM TRANSFER MODELING USING A VOLUME OF FLUID METHOD IN SELECTIVE LASER MELTING OF ALUMINUM BASED COMPOSITES

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Abstract: A selective laser melting (SLM) physical model of coupled radiation transfer and thermal diffusion is proposed, which provides a local temperature field. A strong difference in thermal conductivity between the powder bed and dense material is taken into account. Both thermo-capillary force and recoil pressure induced by the material evaporation, which are the major driving forces for the melt flow, are incorporated in the formulation. The effect of the laser energy input per unit length (LEPUL) on the temperature distribution, melt pool dynamics, surface tension and resultant surface morphology has been investigated. It shows that the surface tension plays a crucial role in the formation of the terminally solidified surface morphology of the SLM-processed part. The higher surface tension of the lower temperature metal near the edge of the melt pool and the thermal-capillary force induced by the surface temperature gradient tend to pull the molten metal away from the center of the melt pool. For a relatively high LEPUL of 750 J/m, the molten material in the center of the melt pool has a tendency to flow towards the rear part, resulting in the stack of molten material and the attendant formation of a poor surface quality. For an optimized processing condition, LEPUL = 500 J/m, a complete spreading of the molten material driven by the surface tension is obtained, leading to the formation of a fine and flat melt pool surface. The surface quality and morphology are experimentally acquired, which are in a good agreement with the results predicted by simulation.

P-6
MOLECULAR SIMULATION OF NANOSCALE FRICTION OF PHOSPHORENE

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Abstract: Nanoscale friction properties of phosphorene play significant roles in designing and precision control of phosphorene-based micro- and nano-mechanical systems. So far, a systematic study of the friction properties, especially the friction anisotropy, of phosphorene is still lacking. In this work, molecular dynamics simulations are employed to explore the friction along various orientations of phosphorene on a silicon substrate by sliding a diamond tip. The results show an "M-shape" friction anisotropy, which means the friction force is locally maximum along the 15º and 75º directions relative to the zigzag direction of phosphorene. It is proposed that this "M-shape" friction anisotropy is due to the difference of potential energy among different orientations arising from the unique structure of phosphorene and heterogeneous interaction with the substrate.

P-7

FROM LAB TO APPLICATION - IMPROVED FRICTIONAL PERFORMANCE OF JOURNAL BEARINGS INDUCED BY SINGLE- AND MULTI-SCALE SURFACE PATTERNS

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Abstract: Friction and wear in mechanical components such as journal bearings tremendously affect the energy efficiency and lifetime. Surface patterning can effectively improve the friction performance of journal bearings. The present study experimentally examines the effect of selected single-scale and multi-scale surface patterns fabricated by roller-coining and/or direct laser interference patterning on the frictional performance of journal bearings. For this purpose, surface patterns showing beneficial effects in preliminary laboratory tests were selected and fabricated with a high accuracy and reproducibility onto the shaft of journal bearings made of stainless steel (AISI 304). The frictional performance of these patterns was evaluated on a specially designed test rig for journal bearings by recording Stribeck-like curves. The results show greatly reduced coefficients of friction and a shift in the transition from mixed to hydrodynamic

lubrication to smaller rotational speeds for all patterned samples compared to the reference sample. The observed friction reduction under mixed lubrication (factor of 2-3) and hydrodynamic lubrication (up to a factor of 4.6) matches well with results observed in the previous laboratory tests. The maximum friction reduction by a factor of 4.6 was observed for the multi-scale sample combining deeper micro-coined dimples with a cross-like laser pattern.

P-8

MICROSTRUCTURAL EFFECT ON THE DEFORMATION BEHAVIOR AND CHIP FORMATION PROCESS OF TEMPERING STEEL DURING HIGH-SPEED SINGLE PASS CHIPPING

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Abstract: Machining processes are widely used to produce industrial goods with a high surface quality and an accurate geometry and for simple products a process force prediction is not necessary. But filigree geometries and hardly machinable materials are a challenge to producers, as chatter marks on the work piece and oscillations in the system and unpredictable tool breakage are unwanted side effects. Possible simulation methods for chip formation, like the local Finite Element Method, are not capable to simulate processes in real time and cannot predict discontinuous deformation bevavior, so a new approach is needed. At that point a deep understanding of deformation and chip formation of materials with varying elastic and plastic properties and a correlation with chip formation, steel grade, heat treatment and, most importantly, with the corresponding microstructure, is required. The single pass pendulum is a suitable model experiment to characterize the deformation and chip formation of materials at large deformation rates and simultaneously measure the cutting force and reaction force. It has been used to investigate differently heat treated samples of a widely used low alloyed steel. The cutting force, reaction force and energy consumption for the chip formation are correlated with the produced chips and the microstructure of both the bulk and the chip, as the chip gives a lot of information about the forming process and the measured forces and vice versa. Results from nanoindentation, micro-scratch tests and Split-Hopkinson Pressure Bar tests are contrasted to the previous results to create a deeper understanding of deformation processes on the microstructural scale. In this context the correlation of microstructure and microstructural properties with macroscopic properties

and deformation characteristics plays a key role.

P-9
NON-ORDINARY STATE-BASED PERIDYNAMIC MODELING OF DUCTILE MATERIAL FAILURE DURING HIGH-SPEED SINGLE PASS CHIPPING

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Abstract: Metal machining is a widely applied manufacturing process for industrial products by removing unwanted material. Milling is a commonly used technique to produce a work piece, but manufacturing very small or thin geometries as well as hard materials is challenging because the material behavior is not always as predicted. This can result in unwanted deformations of the work piece or a bad surface quality. In order to overcome this drawbacks, it is necessary to understand the material response in detail during chipping. Numerical modeling of the material is one approach to acquire a better understanding of the process, but computations with the Finite Element Method still remain difficult due to the presence of cracks and material failure. Therefore, the nonlocal method of peridynamics is introduced, which exhibits a higher stability regarding computations of damage mechanics and material failure. Peridynamics uses a meshless discretization and a connectivity between neighboring points defined in the reference conguration. The non-ordinary state-based peridynamic formulation employs a least-square approach to determine the deformation gradient, which is utilized to constitutive models from classical continuum mechanics. The resulting stresses are converted to the peridynamic force vector state, and an additional stabilization method is applied to prevent zero-energy modes. Furthermore, a critical strain-based damage model is used from the theory of peridynamics, such that damage occurs if a certain elongation is reached. The numerical example presents a cutting simulation of ductile material during high-speed single pass chipping, and the process forces in this context are analyzed.

P-10

TEMPERATURE DEPENDENT CONDUCTIVITY OF SOLUTION-PROCESSED CU2ZNSNS4 THIN FILMS

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Kesterite Copper Zinc Tin Sulfide-Selenide—CZTS(Se) has been an intensively researched material in the last decade. It is a complex material system, which is difficult to characterize. World record efficiency for Kesterite CZTS(Se) reached 12.6%, however still much lower than commercial silicon solar cell. This is because phase purity, morphology and intrinsic defects are difficult to control and affect the CZTS absorber layer performance in optoelectronic device. Temperature-dependent conductivity measurements can provide invaluable insights into the charge transport mechanism taking place in semiconductors. In temperature range, 295-80 K temperature conductivity is analyzed fitting the obtained data. Our study shed lights on the fundamental limitation of a rather disordered solution-processed CZTS sample prepared without sulfurization at high temperature.

P-11

THICKNESS DEPENDENT SURFACE PLASMON OF SILVER FILM PROBED BY NITROGEN VACANCY CENTERS IN DIAMOND

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Abstract: We evaporated a series of silver films with different thickness on diamond.

Using NV center in diamond as a probe, the plasmon-plasmon(PP) coupling on different sides of silver film was measured and analyzed by Green Function (GF) method. And the lifetime of NV center revealed the intensity of PP coupling. It was found that at a specific silver film thickness, there existed a strong plasmon-plasmon modes coupling, thus the lifetime of NV centers reduced to minimum. Also, the lifetime reduction led to the photoluminescence enhancement of NV centers. The results offered an applicable method to detect the properties of SPP in nanostructure. Furthermore, comparing spontaneous emission enhancement of NV centers in experiment and theoretical predications, the depth of NV centers could be determined, which revealed a promising way to detect the depth of the deep NV centers.

P-12
CHARGE TRANSPORT STUDY IN FUNCTIONALIZED SILICON NANOCRYSTALS

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Abstract: 1-ethenyl-4-fluoro benzyl conjugate molecule is grafted on hydrogen-terminated silicon nanocrystals via hydrosilylation process. Films of different thicknesses has been introduced in a proposed device architecture and analysed for charge transport mechanisms. Study of current density-voltage characteristics showed that charge transport follow a power law relationship with an indication of tunneling mechanism as well.

P-13
MODELLING OF SHEET METAL FORMING PROCESSES USING GEOMETRICALLY EXACT EULER-BERNOULLI BEAM-TYPE FINITE ELEMENTS

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Abstract: Metal machining is a widely applied manufacturing process for industrial products by removing unwanted material. Milling is a commonly used technique to produce a work piece, but manufacturing very small or thin geometries as well as hard materials is challenging because the material behavior is not always as predicted. This can result in unwanted deformations of the work piece or a bad surface quality. In order to overcome this drawbacks, it is necessary to understand the material response in detail during chipping. Numerical modeling of the material is one approach to acquire a better understanding of the process, but computations with the Finite Element Method still remain difficult due to the presence of cracks and material failure. Therefore, the nonlocal method of peridynamics is introduced, which exhibits a higher stability regarding computations of damage mechanics and material failure. Peridynamics uses a meshless discretization and a connectivity between neighboring points defined in the reference conguration. The non-ordinary state-based peridynamic formulation employs a least-square approach to determine the deformation gradient, which is utilized to constitutive models from classical continuum mechanics. The resulting stresses are converted to the peridynamic force vector state, and an additional stabilization method is applied to prevent zero-energy modes. Furthermore, a critical strain-based damage model is used from the theory of peridynamics, such that damage occurs if a certain elongation is reached. The numerical example presents a cutting simulation of ductile material during high-speed single pass chipping, and the process forces in this context are analyzed.

P-14

MICROMACHINING OF BIONIC SURFACE STRUCTURES FOR GRIBOLOGICAL OPTIMIZATION OF FORMING PROCESSES

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Abstract: The increase of functional requirements on technical surfaces, e.g. of moulds and dies for sheet-bulk metal forming, require a continuous optimization of the design of forming tools. Especially the filling of the filigree form elements in this forming process is a major challenge. In addition to conventional coating systems,

microstructures can be applied in order to adapt the tribological characteristics of the tool surface and, therewith, to control the material flow.

Due to the microscopic dimensions of a single structural element, the production of these structures is mainly investigated by laser ablation and erosion processes, since these processes provide a sufficient precision. Micromachining of such structures has hardly been researched. However, this manufacturing process offers a number of advantages which favour the use of this process for structuring components. In addition to a high surface quality, it is also possible to achieve a considerably higher ablation rate, which results in a significantly shorter process time. Furthermore, a low process temperature prevents a thermal influence of the subsurface, which avoids negative effects on the technical properties of the microstructure.

This presentation shows a selection of bionic microstructures, which are derived from highly resistant surfaces which can be found in nature. In addition to the structural design, the manufacturing process and the influence of the structures on the material flow are also discussed.

P-15

THE STRESS-VELOCITY RELATIONSHIP OF TWINNING PARTIAL DISLOCATIONS AND THE PHONON-BASED PHYSICAL INTERPRETATION

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Abstract: The dependence of dislocation mobility on stress is the fundamental ingredient for the deformation in crystalline materials. Strength and ductility, the two most important properties characterizing mechanical behavior of crystalline metals, are in general governed by dislocation motion. Recording the position of a moving dislocation in a short time window is still challenging, and direct observations which enable us to deduce the speed-stress relationship of dislocations are still missing. Using large-scale molecular dynamics simulations, we obtain the motion of an obstacle-free twinning partial dislocation in face centred cubic crystals with spatial resolution at the angstrom scale and picosecond temporal information. The dislocation exhibits two limiting speeds: the first is subsonic and occurs when the resolved shear stress is on the order of hundreds of megapascal. While the stress is raised to gigapascal level, an abrupt jump of dislocation velocity occurs, from subsonic to supersonic regime. The two speed limits are governed respectively by the local transverse and longitudinal phonons associated with the stressed dislocation, as the two types of phonons facilitate dislocation gliding at

different stress levels.

P-16
THE STRESS-VELOCITY RELATIONSHIP OF TWINNING PARTIAL DISLOCATIONS AND THE PHONON-BASED PHYSICAL INTERPRETATION

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Abstract: Brain is an extraordinary sophisticated organ responsible for a series of physical and mental work, whereas it is sensitive and vulnerable under potentially injurious circumstance. Compared with major efforts which focus on the biochemical behavior of brain, it is away from the spotlight that how the brain functions at the mechanical level, especially in the fields regarding clinical application. Compare with other traditional testing methods, Indentation is considered as a powerful tool for the characterization of brain tissue by virtue of its unrestriction of tissue morphology and region-specific down to micro- and nanoscale. Using indentation method, it is found that some factors involved in clinic, such as strain rate and electric fields, greatly influence the mechanical behavior of brain tissue.

P-17
STUDY ON THE MACHINING MECHANISM OF DIAMOND TURNING OF MICROLENS ARRAY ON ELECTROLESS NICKEL PHOSPHORUS PLATING

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Abstract: Microlens array has been widely used in optoelectronic systems. Single crystal diamond cutting is one of the main technologies for machining microlens arrays, in the process of which the machining track and cutting parameters have great influence on the quality of microlens array. In the present work, a compound eye microlens array is fabricated on the electroless nickel phosphorus plating at different feeds. The formation mechanism of defect at adjacent area of microlens was studied, and an innovatively designed machining track was proposed to eliminate the defect and then verified by experiments. In addition, the effects of feed, C-angle increment and the tool nose radius on the form accuracy and the surface roughness of microlenses at different locations are studied. Finally, the form accuracy and surface roughness prediction models of microlens are proposed, and an innovative method is proposed to improve the uniformity of the square compound eye microlens array.

P-18

NUMERICAL MODELING OF CYCLIC NANO-INDENTATION USING CHABOCHE MATERIAL MODEL

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Abstract: Depth-sensing indentations are very useful experiments for determining mechanical properties (i.e. Young's modulus and hardness) of thin films as well as bulk materials. The aim of this work is to investigate cyclic indentation experiments instead of conventional load-unload experiments using finite element method. Numerical simulations for Vickers indentation are performed using Chaboche material model with three backstress terms in order to capture the experimental cyclic indentation curve. Different aspects of numerical modeling like element size, element type and integration scheme are also investigated in the scope of this work.

P-19

INVESTIGATION OF GA ION IMPLANTATION-INDUCED DAMAGE IN SINGLE CRYSTAL 6H-SIC AND 4H-SIC

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Abstract: Silicon carbide (SiC) is considered as a third-generation semiconductor. It has been found that SiC is useful for amazing applications across several engineering disciplines. In the present work, in order to investigate the damage in single crystal 6H-SiC and 4H-SiC in dependence on ion implantation dose, ion implantation experiments were performed using Focused Ion Beam technique. Raman spectroscopy and Electron BackScatter Diffraction (EBSD) was used to characterize the SiC samples before and after ion implantation. Monte Carlo simulations were applied to verify the characterization results. Surface morphology of the implantation area was characterized by scanning electron microscope (SEM) and atomic force microscope (AFM). The "swelling effect" induced by low dose ion implantation of 10^{14}~10^{15} ions/cm^2 was investigated by AFM. The typical Raman bands of single crystal SiC were analyzed before and after implantation. The study revealed that the thickness of amorphous damage layer was increased and then became saturated with increasing ion implantation dose. The critical dose threshold (2.81×10^{14}~3.26×10^{14} ions/cm^2) and saturated dose threshold (~5.31×10^{16} ions/cm^2) for amorphization were determined. Damage formation mechanisms were discussed, and a schematic model was proposed to explain the damage formation.

P-20

3D Bio-printed Compound Material Artificial Vascular Substitute with Electroprinted Polycaprolactone (PCL) and Photo Cross-linked Hydrogel Gelatin Methacryloyl (GelMA)

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Abstract: Vascular system is the basic element existing in almost any tissue or organ in human body, which provides the tissue with nutrition and brings its metabolic waste away. Meanwhile, 3D bioprinting technology also requires efficient artificial vascular system to support a printed tissue in large scale. Many researches have been conducted to construct artificial vascular substitute both having nice mechanical properties and biocompatibilities, but very few of the materials can meet these two requirements. For example, polyurethane is a commonly used material in artificial vascular substitute which can endure millions of times of the impact caused by the blood pressure, but hardly can any cell live on it and then results in thrombus due to the absence of factors produced by vascular endothelial cells. On the other hand, collagen is a kind of material that is the main component of extracellular matrix, yet its poor mechanical strength limits its use in artificial blood vessels. Consequently, a tubular compound material artificial structure, which is strong enough to endure blood pressure or suture force during surgery and support the adhesion, proliferation and functionalization of vascular endothelial cells, is expected to be promoted.

P-21

A NOVEL ULTRASONIC ELLIPTICAL VIBRATION CUTTING DEVICE BASED ON A SANDWICHED AND SYMMETRICAL STRUCTURE

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Abstract: Ultrasonic elliptical vibration cutting (UEVC), which is a promising cutting technique, has been extensively applied to the precision machining of difficult-to-cut materials and the fabrication of micro-nano structure. This paper presents a new ultrasonic elliptical vibration cutting (UEVC) device based on a sandwiched and symmetrical structure. The proposed UEVC device is able to work with the 3rd resonant mode of longitudinal vibration and the 6th resonant mode of bending vibration. Also, the vibration nodes of the two resonant modes were completely superposed at the center of the flange. Therefore, the single node fixed method was employed, which was practical and had no interference to the resonance mode of the UEVC device. The modal analysis of the designed UEVC device was performed by using finite element method. The results revealed that the modal degeneration can be realized by optimizing design parameters. Based on the optimized results, a prototype UEVC device was manufactured, and its vibration characteristics were evaluated by an impedance analyzer and a laser displacement sensor. The measurement results indicated that the resonant

frequencies were close to the simulation frequencies and an elliptical trajectory was generated at the tool tip. Finally, the proposed UEVC device was integrated into an ultra-precision machine tool to confirm the feasibility of the designed UEVC in the practical application.

P-22

ELECTROPHORETIC DEPOSITION OF LAWSONE LOADED BIOACTIVE GLASS (BG)/CHITOSAN COMPOSITE ON POLYETHERETHERKETONE (PEEK)/BG LAYERS AS ANTIBACTERIAL AND BIOACTIVE COATING

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Abstract: In this study, chitosan/bioactive glass (BG)/lawsone coatings were deposited by electrophoretic deposition (EPD) on polyetheretherketone (PEEK)/BG layers (previously deposited by EPD on 316L stainless steel) to produce bioactive and antibacterial coatings. Firstly, the EPD of chitosan/BG/lawsone was optimized on stainless steel in terms of suspension stability, homogeneity and thickness of coatings. Subsequently, the optimized EPD parameters were used to produce bioresorbable chitosan/bioactive glass (BG)/lawsone coatings on PEEK/BG layers. The produced layered coatings were characterized in terms of composition, microstructure, corrosion resistance, in-vitro bioactivity, drug release kinetics and antibacterial activity. Ultraviolet/Visible (UV/VIS) spectroscopic analyses confirmed the release of lawsone from the coatings. Moreover, the deposition of chitosan/BG coatings was confirmed by Scanning Electron Microscopy (SEM) and Fourier Transform Infrared spectroscopy (FTIR). The coated specimens presented higher corrosion resistance (ten times) in comparison to that of bare 316L stainless steel and showed convenient wettability for initial protein attachment. The presence of lawsone in the top layer provided antibacterial effects against Staphylococcus carnosus. Moreover, the developed coatings formed apatite-like crystals upon immersion in simulated body fluid, indicating the possibility of achieving close interaction between the coating surface and bone.

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MICROMECHANICAL MODELING OF DP600 STEEL: DERIVATION OF BARLAT YLD 2004-18P YIELD FUNCTION

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Abstract: Because the microstructure consists of constituents with strong differences in their mechanical properties, dual phase steels exhibit remarkably high-energy absorption along with an excellent combination of strength and ductility. Under the circumstances in which modern sheet metal forming processes, involving complicated load paths, are applied, different deformation mechanisms in the heterogeneous microstructure need to be taken into account. With the help of the micromechanical modeling approach that considers the influence of microstructural features on the mechanical response of materials, this demand can be well met.

This study proposes a micromechanical modeling scheme to determine parameters for an advanced yield function. In this work, we choose the Barlat YLD2004-18p model because of its flexibility to describe the anisotropic yield behavior. In the first part, microstructure of DP600 steel is quantitatively characterized using the EBSD analysis to gain relevant statistical information of all important microstructural features such as phase volume fractions and grain size distributions and orientation distributions of each constituent. The obtained results are then used to generate the microstructure model with the help of an advanced dynamic microstructure generator (ADMG), which combines a particle simulation method with radical Voronoi tessellation to construct proper grain size and orientation distributions. Finite element simulations with a non-local crystal plasticity model for the individual grains are then conducted under the uniaxial tension loading condition. With the help of these simulations, crystal plasticity parameters are adapted to match the experimental results. Subsequently, an algorithm to construct the yield surface based on the CP-FEM simulation is developed. The primary objectives of this proposed algorithm are to automatically capture and extract the yield loci under various loading conditions. Finally, a nonlinear least square optimization is applied to determine the material parameters of Barlat YLD 2004-18p initial yield function of the DP600 steel.

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EFFECTS OF SURFACE MODIFICATION ON BIOCOMPATIBILITY OF MEDICAL TITANIUM ALLOYS

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Abstract: Physicochemical surface properties of biomedical titanium alloy， as a key factor affecting the biological behavior of cells, determine the bone-implant bonding quality and the rates of integration. A series of advances were obtained in our previous research of surface modification technology on titanium alloy. The micro/nano-hierarchical structure was obtained on the surface of titanium alloy by both mechanical processing (such as micro-milling, laser processing and sandblasting) and chemical treatment (including acid etching, alkali heat treatment and anodizing) for preparation of surface morphology. For the surface chemical composition, bioactive ions were implanted on the micro/nano-structured surface by ion exchange. The quality of surface passivation film was improved using the oxygen-rich cutting method. The effects of surface modification methods on the biocompatibility of titanium implants were verified by electrochemical corrosion tests and a series of cell culturing experiments in vitro. The results showed that the wettability of the material was improved and the cell adhesion, proliferation and mineralization were promoted with micro/nano-structured surface. Besides, the implantation of bioactive ions further enhanced the biocompatibility of implants because of the synergistic effect with the micro/nano-structure. In addition, the thickness of oxide film on titanium alloy surface increased significantly in the oxygen-rich processing atmosphere compared to the natural condition, which improved the biocompatibility of and corrosion resistance simultaneously.

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A NOVEL AFM-BASED 5-AXIS NANOSCALE MACHINE TOOL FOR FABRICATION OF NANOSTRUCTURES ON A MICRO BALL

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Abstract: This paper presents a novel atomic force microscopy (AFM)-based 5-axis nanoscale machine tool developed to fabricate nanostructures on different annuli of the micro ball. Different nanostructures can be obtained by combining the scratching trajectory of the AFM tip with the movement of the high precision air-bearing spindle. The center of the micro ball is aligned to be coincided with the gyration center of the high precision to guarantee the machining process during the rotating of the air-bearing spindle. Processing on different annuli of the micro ball is achieved by controlling the distance between the center of the micro ball and the rotation center of the AFM head. Nanostructures including square cavities, circular cavities, triangular cavities, and an annular nanochannel are machined successfully on the three different circumferences of the micro ball with a diameter of 1500 μm. Moreover, the influences of the error motions of the high precision air-bearing spindle and the eccentric between the micro ball and the gyration center of the high precision air-bearing spindle on the processing position error of the micro ball are investigated. This proposed machining method has the potential to prepare the inertial confinement fusion target with the expected dimension defects, which will extend the application of the AFM tip-based nanomachining approach.

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MOLECULAR DYNAMICS SIMULATIONS OF PARTICLE BEHAVIORS IN MAGNETORHEOLOGICAL POLISHING

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Abstract: Material removed in magnetorheological polishing is primarily produced by abrasive particles in magnetorheological polishing fluid. Thus, the contact states and motion behaviors of abrasive particles in magnetorheological polishing definitively influence the polishing quality and efficiency. In the present work, coarse-grained molecular dynamics method was adopted to analyze the motion behaviors of particles in magnetorheological polishing process. Both of the carbonyl iron particles and abrasive particles were involved in the molecular dynamics simulation model. In the simulation,

the influences of particle concentration, particle size and magnetic field gradient on particle behaviors were studied both from theoretical analysis and numerical simulation. The results indicate that the three parameters have a great impact on the particle behaviors under magnetic field

About the symposium

The 2nd Sino-German Symposium “Material-Oriented Micro/Nano Manufacturing”, held in Bochum (Germany), pursues the main objective to further enhance and strengthen the cooperations that have resulted from the 1st Sino-German Symposium in September 2017 at the Harbin Institute of Technology, Harbin/China.

In addition, it further explores scientific synergies between nano-machining, nano-manufacturing, and wear by bringing together engineers and scientists from Germany and China from different disciplines of mechanical engineering, fabrication technology, and materials science who normally would not meet in a single scientific conference and thus providing a platform for scientific exchange and in-depth discussions.

Furthermore, the 2nd symposium not only addresses scientists involved in fundamental numerical or experimental studies of micro- and nano-manufacturing, but it will also strengthen the application aspects of this subject, from which new scientific challenges arise. The topics to be covered in the 2nd symposium include:

- micro/nano-fabrication technologies and key components
- process analysis and characterization, modeling and simulation
- surface engineering
- research synergies between precision machining and wear.